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ABSTRACT

This pamphlet offers information to teachers and students concerning basic facts about weather and how to construct simple weather measurement devices. Directions, necessary materials, procedures, and instructions for use are given for four weather predicting instruments: wind vane, rain gauge, barometer, anemometer. Information is provided on weather and radar, weather satellites and radiosonde instruments, weather signs, clouds, lightning, hurricanes, tornadoes, and air pollution. Photographs and drawings accompany the text. (SA)

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Basic Weather Facts
Study texts for students

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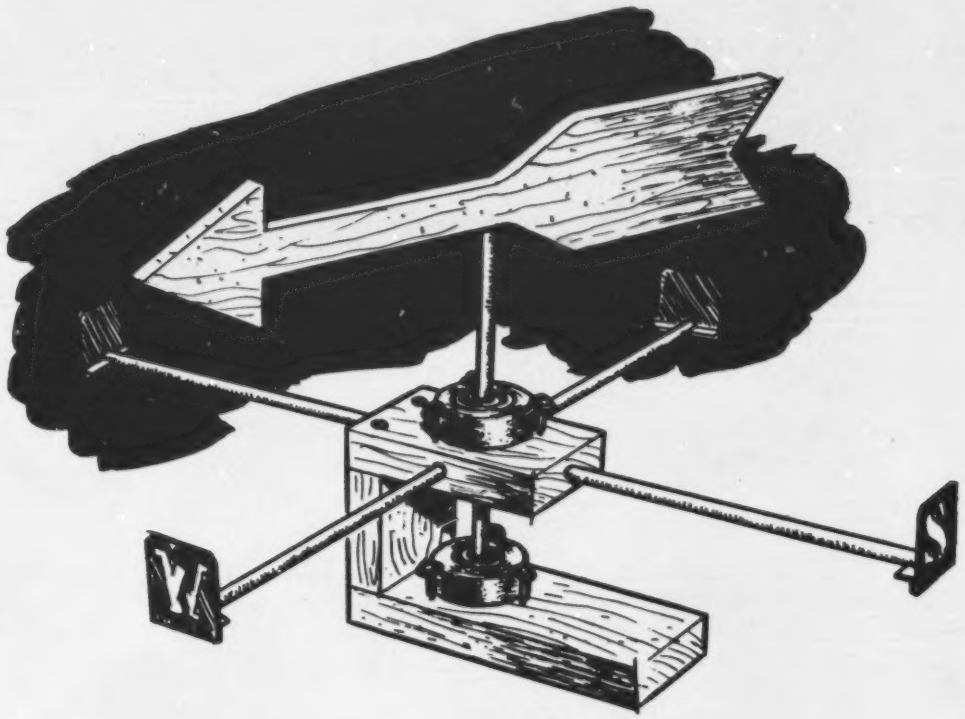
DETERMINING THE WIND DIRECTION

It's a basic weather rule that "the winds bring the weather", and an amateur weatherman can become adept at foretelling future conditions by associating the wind direction with other weather signs.

A simple wind direction instrument as illustrated can be constructed from a few basic materials.



You'll need 4 pieces of wood about 3/4" (19 mm)* thick and of the following approximate dimensions:

10 x 18 cm (for bottom of base)
10 x 10 cm (for top of base)
10 x 8 cm (for upright part of base)
40 x 8 cm (for arrow)
2 roller skate wheels
6 large-headed screws about 1"–2" (2.5 x 5 cm) long, with washers
5 dowels (round sticks) about 1/4" (6 mm)* diameter 20 cm long
4 pieces of metal about 5 x 5 cm (for direction letters)
glue

*Where applicable, dimensions are given in inches as well as in millimetres, since both are used by industry.

Making the Instrument

1. Cut out arrow from largest piece of wood. The tail of the arrow should be made much larger than the head to obtain best results. It's a help to draw half the arrow along the fold of a piece of folded paper, then cut around the outline. When the paper is opened flat it will provide a pattern with uniform shape for both halves.

2. Find the point of balance of the arrow, drill a hole at this point and glue one dowel into the hole.

3. Drill 1/2" (1.3 cm) hole through top of base and half way through bottom of base.

4. Fasten skate wheels over each hole with 3 large-headed screws.

5. Force dowel attached to arrow through holes of wheels so that the bottom of the dowel doesn't quite touch the wood base. Wax the end of the dowel so that it won't bind as it turns.

6. Glue remaining dowels into holes drilled around top of base. Paint letters on each of metal squares (N, E, W, S) and tack these directional letters to the ends of the dowels.

Mounting the Instrument

Erect the instrument in a location free from wind obstructions and well off the ground. If possible, line up the N marker with the North Star in order to properly position the directional letters. A pocket compass may also be used to determine the positioning but the readings will be magnetic rather than true bearings.

Using the Instrument

You'll notice that the arrow will point into the wind and therefore will indicate the direction *from which* the wind is blowing.

The arrow will vary in position from minute to minute especially if it is located where there are gusts and eddies caused by surrounding obstructions.

You may be surprised to find that cloud, rain and snow do not always come from the direction from which the surface wind is blowing. However, experience will teach you what wind directions in your locality are most likely to bring fair weather, rain or snow.

MEASURING RAINFALL

A simple instrument for collecting and measuring rainfall is called a rain gauge. Here is a way of making such an instrument yourself.

YOU'LL NEED

1. Tin can, open at top, with no lip, so you can pour rain out of it easily.
2. Wood to make a little platform (a log or a box stuck into the ground on end will also do).
3. Ruler
4. Tall glass jar (a very narrow one with straight sides like an olive jar, chili sauce bottle, Alka-seltzer bottle, etc.)

TO MAKE IT

1. Make stand of wood, log, box, etc., to hold tin on top so it won't fall off. The open top of can should be level and about 30 centimetres above the ground.

2. To calibrate jar: pour one centimetre of water into tin can. Pour this water into tall jar and mark water level with grease pencil or paint. This will be the mark for one centimetre of rain. From this first mark you can measure and mark up tenths of centimetres all the way to the top of the jar.

TO USE IT

Put rain can as far away from buildings, trees, fences, etc., as possible so they won't interfere with rain catch. Pour rain from can into calibrated jar and read off rainfall in centimetres and tenths of centimetres (millimetres). Read rain can at least once a day, or better still, twice a day, at regular times, say at breakfastime and at suppertime.

NOTE

To measure snow, just use a ruler; stick it into snow at several points in the yard; average the readings; distinguish between old and newly fallen snow. Ten centimetres of snow equal one centimetre of rain.

WORLD RAIN RECORDS

Average precipitation around the world	– 84 cm a year
Greatest rainfall amount in 24 hours	– 116.8 cm at Baguio, Luzon, Phillipines, July 14-15, 1911.
Greatest rainfall amount in one year	– 2,299 cm at Cherrapunji, Assam, India, 1861.
Greatest average annual rainfall	– 1,199 cm at Mount Weialeale, Kauai, Hawaiian Islands.
Least average annual rainfall	– 0.05 cm at Arica, Chile

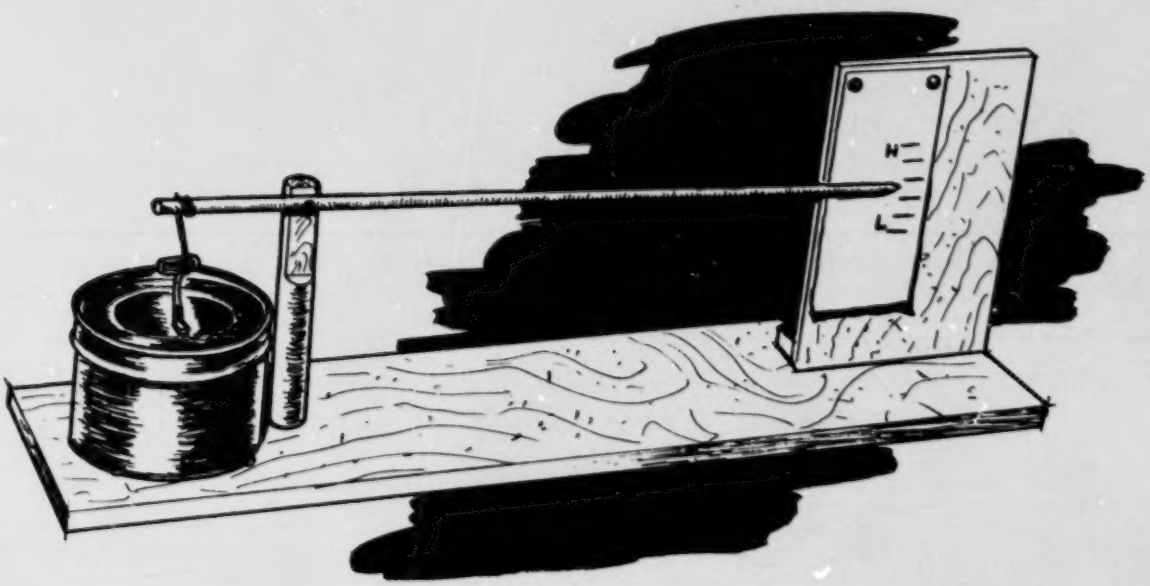
CANADIAN PRECIPITATION RECORDS

	Least Average Annual Precipitation	Greatest Average Annual Precipitation
British Columbia	19.51 cm at Ashcroft	664.97 cm at Henderson Lake
Alberta	19.25 cm at Empress	105.16 cm at Waterton Park
Saskatchewan	23.75 cm at Alsask	47.63 cm at Bangor
Manitoba	32.94 cm at Grass River	64.19 cm at Deerwood
Ontario	54.76 cm at Heaslip	105.59 cm at Parry Sound
Quebec	34.52 cm at Cape Hopes Advance	151.31 cm at Barriere Tourilli
New Brunswick	76.45 cm at Burnt Church	144.73 cm at Saint John
Nova Scotia	94.39 cm at St. Paul Island	168.33 cm at Ingonish Beach
Prince Edward Island	83.39 cm at Alliston	110.46 cm at Charlottetown
Newfoundland	51.84 cm at Cape Norman	165.96 cm at Cluny's

MEASURING THE AIR PRESSURE

We live at the bottom of an ocean of air. The weight of this air is constantly changing and these changes in weight or pressure often are significant warnings of weather to come. However, the actual weight of the air at any one time is not nearly as important as is the manner in which the weight is changing – especially if it's becoming steadily greater or steadily less.

The instrument used to measure air pressure is a barometer. The simple barometer illustrated below can be readily constructed from a few ordinary materials.



You'll need
- 1 piece of wood about 3/4" (19 mm)* thick and approximately 60 x 15 cm (for base)
- 1 piece of wood about 1/2" (13 mm)* thick and approximately 20 x 12 cm (for upright scale)
- 1 round piece of wood about 1/4" (6 mm)* in diameter, 50 cm long and sharpened to a point at one end.
- 1 piece of wood 1/2" x 1/2" x 6" (13 mm x 13 mm x 15 cm)* (post for pivotting pointer)
- 1 piece of stiff wire or a paper clip
- 1 unopened tin of vacuum-packed coffee or peanuts
- screws
- glue

*Where applicable, dimensions are given in inches as well as in millimetres, since both are used by the lumber industry.

Making the Instrument

1. Fasten the coffee tin securely to one end of the base by screws spaced snugly around the circumference (do not puncture the tin).

2. Carefully bend the key on top of the tin to a right angle. Hint: a touch of solder at the bend may keep the key from snapping off later.

3. Fasten the 15 cm post in a vertical position at the edge of the tin nearest the centre of the base.

4. Drill a hole about 9 cm from the end of the pointer and pivot the pointer on a screw passing into the vertical post.

5. Connect the key and the end of the pointer by a stiff wire so that the pointer is about horizontal.

6. At the end of the pointer and parallel to it, nail the 20 x 12 cm piece of wood in a vertical position (close to, but not touching, the pointer).

How the Instrument Works

You will note that the end of the pointer will move slowly upwards when the top of the coffee tin sinks slightly inward due to increasing air pressure. When the pointer moves downwards this will be a result of decreasing air pressure.

Because most of the air has been taken out of the coffee tin to make it a partial vacuum, the changes in weight of the air outside the tin cause the lid to cave in or bulge. This movement is magnified in the movement of the pointer.

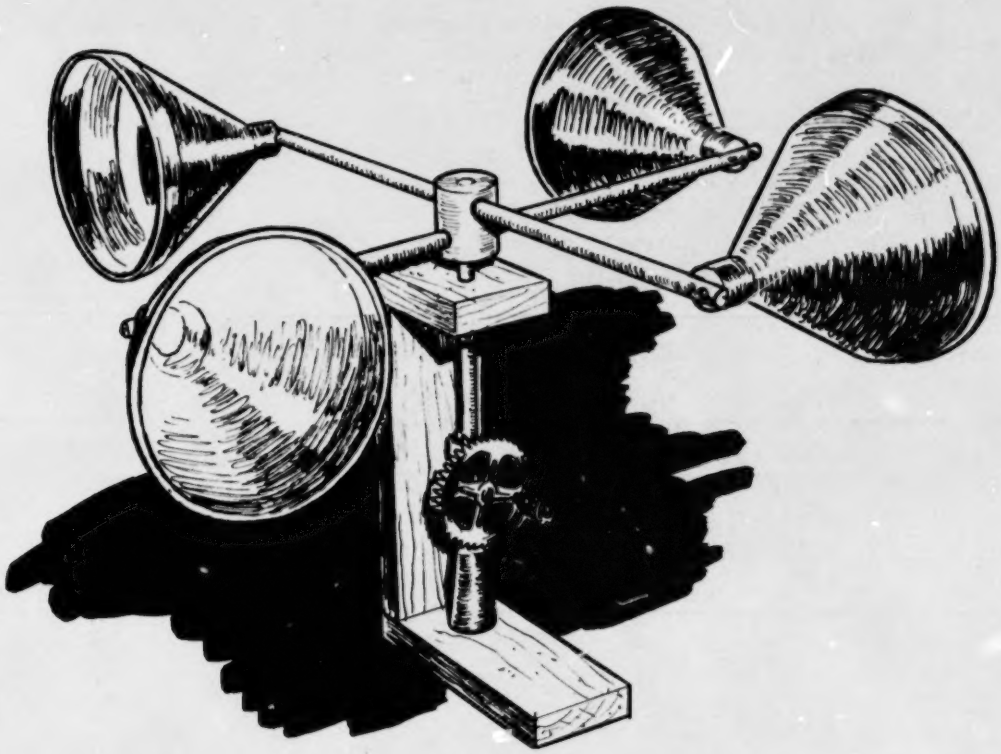
How to use the Instrument

Increasing pressure is usually an indication of fair weather and falling pressure usually indicates bad weather. But your experience in watching your barometer will soon tell you that this is not always the case. It's best to associate the changes in the barometer reading with other weather signs – wind direction, cloudiness, etc.

For instance, you will often find that when the wind blows steadily from the south-east and the pressure is falling rapidly rain soon begins. You'll develop other local rules which will become apparent to you when you consider changes in your barometer reading together with other changes in weather elements.

MEASURING THE WIND SPEED

Amateur weathermen learn to estimate the speed of the wind by noting its effect on branches of trees, leaves, smoke, water surfaces etc. But a more reliable method is to have an instrument which measures the wind speed. Here is a method of constructing a simple form of such an instrument.



You'll need 3 pieces of wood about 3/4" (19 mm)* thick and of the following approximate dimensions:

20 x 10 cm (for bottom of base)
10 x 10 cm (for top of base)
25 x 10 cm (for upright part of base)
1 hand drill
4 dowels (round sticks about 3/8" (10 mm)* diameter) 25 cm long
1 dowel 10 cm long
4 plastic funnels about 12 – 15 cm in diameter at widest part
1 large wooden spool (carpet thread type) or dowel 1 3/8" (35 mm)* diameter and 4 cm long
screws
4 wooden plugs to fit snugly in cut-off ends of funnels
glue

*Where applicable, dimensions are given in inches as well as in millimetres since both are used by the lumber industry.

Making the Instrument

1. Saw the wooden handle off the hand drill. Run a screw through the bottom of the base into the wooden handle.

2. Drill a hole in the centre of the top of the base, wax the 10 cm dowel and slip it through the hole. Fasten this dowel to the hand drill.

3. Drill holes on 4 sides of the spool or dowel (spaced evenly apart) and glue in dowels to form arms at right angles.

4. Glue spool or dowel to upright dowel attached to hand drill.

5. Shorten the ends of the funnels. Fasten the funnels to the arms by screws into the plugs. Make sure the funnels all point in the same direction.

Calibrating the Instrument

To give a reasonably accurate reading the instrument must be calibrated. One way of doing this is to have someone drive you in a car on a windless day. Hold the instrument at arm's length out the window and have the driver proceed at an even speed starting at five kilometres per hour. Count the number of turns the beater handle makes in 60 seconds. Do the same at ten kilometres an hour and so on in five kilometre intervals to 65 kilometres per hour. Speeds above this lead to velocities beyond the ability of the instrument to measure. As a check on your calibrations, repeat the readings with the car travelling in the opposite direction.

Chart the information in two columns with wind speed on one side and revolutions of the handle per minute in the other. Then it will be easy to translate the revolutions per minute into speed in kilometres per hour. For quicker readings count the turns in one half minute and double this number to get the wind speed.

Mounting the Instrument

Erect the instrument in a location free from wind obstructions and as high as possible, remembering of course that you must be able to see the handle in order to count its revolutions.

THE WEIGHT OF THE AIR

We live in an ocean of air. It has weight just as the waters in the ocean have weight. The atmosphere, extending many kilometres upward, presses down on the surface of the earth with a weight of about 1.05 kilograms per square centimetre or about 18 metric tons on the body of an average adult. A standard sized house contains about 500 kilograms of air, and the weight of the atmosphere on a single square kilometre of the earth's surface is about 10 million metric tons. As one climbs a mountain there is less and less air above, and at the top of Mount Everest at an altitude of 8,840 metres, the weight of the air is only one third as much as at the surface. Because the weight of the air above compresses the air below, about half the total weight of the air is concentrated in the five-kilometre layer closest to the earth. The higher one goes, the thinner the air becomes and it becomes necessary to use oxygen masks or pressurized aircraft above a height of about 3,000 metres.

At the earth's surface water boils at 100°C but the boiling point of water decreases as air pressure decreases at about 1°C for each rise of 300 metres. At 3,660 metres where water boils at 87°C it takes seven minutes to boil a "three-minute" egg. People living in the mountains of Chile at the 5,300 metre level have developed, as a result of prolonged exposure to "thin" air, long, large hearts, large chests and slow heart beats.

MEASURING THE WEIGHT OF THE AIR

In the 17th century an Italian scientist, Torricelli, found that the weight of the atmosphere could be balanced by the weight of a column of mercury enclosed in a glass tube. The pressure of the air was equal to about 76 centimetres of mercury and ever since that time we have measured air pressure in centimetres of mercury. From Torricelli's experiments the modern mercury barometer was developed and refinements have led to a very accurate instrument which is used in weather observing throughout the world. However, because it is cumbersome and fragile, it is unsuitable for general use in offices and homes.

The aneroid barometer is an ideal instrument for home use and its operation is quite simple. The dial is generally graduated in "centimetres of mercury", while inside the instrument is a thin metal cylinder partially evacuated of air. This cylinder responds to changes in air pressure in an accordion-like manner. The minute movements of the surface of the cylinder are amplified by a system of levers connected to a movable hand; the pressure may be read directly from the dial.

SETTING YOUR BAROMETER

A few days after Christmas, or Father's Day, weather offices across Canada receive many phone calls asking how to set gift barometers so that they will record the pressure accurately and can be used in forecasting the weather. The amount of pressure change and whether the pressure is rising or falling are more signficant than the actual barometer reading. Therefore, it is not really necessary to "set" a barometer accurately unless one wishes to know the value of the pressure at any time. The movement of the hand will always reflect the changes in atmospheric pressure. However, many people like to be able to compare their barometer readings with the values quoted in the newspapers, or by TV and radio weathermen. The following advice will enable you to set your barometer so that its readings will be comparable with the readings of nearby weather stations.

(Note: Weather reports express barometric pressure in "kilopascals" (kPa): 76.0 cm of mercury = 101.3 kPa, or 1 cm of mercury = 1.33 kPa.)

1. First note the reading of the black hand. This is your "station" pressure now. On the back of the instrument there is a small hole. In the hole is a little set screw which can be easily turned with a small screw-driver. Test it by turning it gently back and forth. You will note that the black hand on the dial moves in response to the turning of the screw.
2. If you live near a weather office call and obtain the barometer reading in centimetres corrected to sea level. Then set the black hand on your barometer to read the same value.
3. If there is no weather office nearby you can use a table of figures to determine the correction required at any elevation above sea level. These tables are available from barometer manufacturers and are included in most books of mathematical tables. But you must know the height of your location above sea level. This information can be obtained by consulting your civic engineer, local railroad agent or a good road or topographical map. You will find from the tables, for instance, that for an elevation of 120 metres you move the black hand so as to add 1 centimetre; or for 240 metres you add 2 centimetres. This amount is to be added to whatever the value was before any change was made.

THE BAROMETER AND TOMORROW'S WEATHER

First of all, do not put much faith in the legends that are usually marked on the face of your barometer. Despite the words "stormy", "rain", "change", and "fair" you may often find the hand points to "rain" when the sun is shining.

Weather changes are usually related to changes in the weight of the air overhead. The high pressure areas and low pressure areas on a weather map are indications of this weight of the air. In general these pressure areas move from west to east in Canada accounting for the fact that our weather usually moves from west to east. The weather associated with high pressure areas is usually fine, while low pressure weather is often stormy.

As these pressure areas move towards, over and past you, your weather-glass faithfully shows the change in the total weight of the air overhead. It won't take you long to learn the ways of your barometer. Read it carefully and regularly. At fixed times note down the barometer reading, its rate of rise or fall, the wind direction and the actual weather. In a few short weeks you'll begin to tie together the pressure, the wind and the weather elements and to make weather forecasts for your locality. You'll soon decide that the barometer reading alone doesn't tell the whole story but when associated with the current wind and weather you can draw some useful conclusions which help in predicting tomorrow's weather.

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WEATHER AND RADAR

ORIGIN OF THE WORD

The word "RADAR" came from the phrase "RAdio Direction And Ranging"; another example of the modern trend to abbreviation which, in this case, has produced something pronounceable.

HISTORY

While most people think that radar was a by-product of World War II brought about by military necessity, this is true only to the extent that during the last war radar equipment suitable for practical use was first produced. Away back in 1887 the underlying principle of radar was first observed by the physicist Hertz. He found that electromagnetic (radio) waves had some properties similar to those of light waves in that they could be reflected from objects and focused into beams by the use of reflectors. Radar was not suddenly discovered but developed gradually from the initial investigations of the German scientist.

Under the direction of Sir Robert Watson-Watt successful radar equipment was first produced in England in 1935, leading to the establishment of the early aircraft warning system which played so vital a role in the battle of Britain.

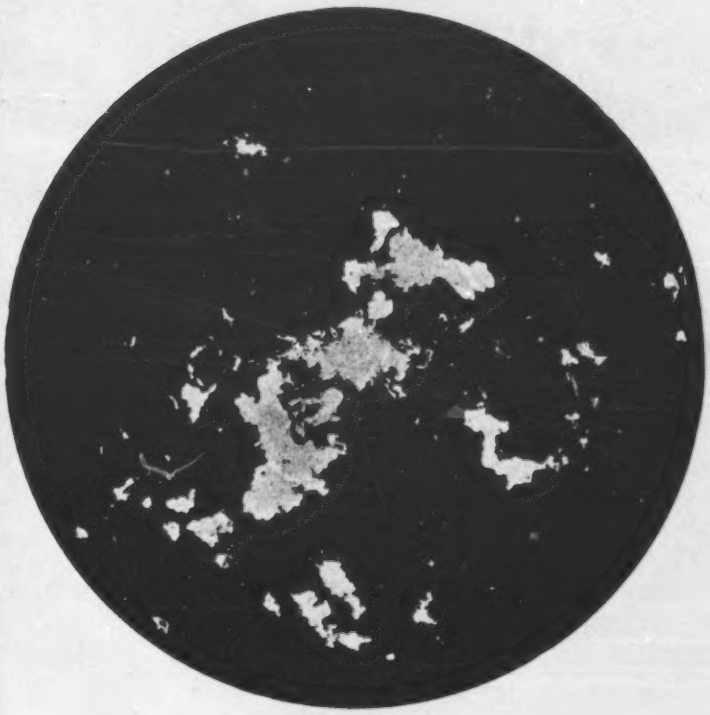
In the application of radar to the detection of enemy aircraft, it was soon discovered that precipitation areas also showed up on the radar screen. Meteorologists had been presented with an immensely valuable new tool!

HOW DOES RADAR WORK?

The reflection of radio waves from targets is very similar to the reflection of sound waves. Everyone is familiar with the way sound reflects from the face of cliffs, particularly in a narrow valley, or from the walls in a long hallway resulting in the well known "echo" or reverberation. In exactly the same manner, the ordinary electromagnetic waves used to bring radio and television into the home are reflected from objects in the path of the waves. If a radio wave strikes some object in its path, a very small amount of energy will be reflected back to the point of transmission.

In the pulsed radar system, radio waves are emitted in short, powerful bursts, focused in a narrow beam, like that from the headlight of a locomotive, and radiated into space by a slowly rotated antenna. The pulse duration is usually only one or two millionths of a second with the interval between the pulses called the silent period, when there is no wave emission, being somewhat greater. When these bursts of energy, travelling at the speed of light, 300,000 kilometres per second, strike an object such as an aircraft, ship, rain, snow, or hail, a very small portion of the energy is returned to the radar set as an echo. Since radio waves travel at the speed of light and the direction in which the antenna is pointing can be controlled, it is possible to determine the distance and direction of a target. Detected by the radar antenna during the silent period, the echo is fed from the antenna to the radar receiver where it is amplified and changed to a video signal for display purposes.

The display unit, called "radarscope", is very similar to a TV screen. Radar echoes can be displayed in several ways. The main "radarscope", called a PPI (Plan Position Indicator), gives a picture in a map-like form and shows echoes in range and direction from the centre of the picture which is the site of the radar. All the detected echoes are pictured on the PPI with each rotation of the antenna and during each subsequent rotation the picture is erased and a new one presented. Another type of display, called the RHI (Range Height Indicator) shows precipitation echoes in range and height along the direction of the radar beam and is obtained when the antenna is not rotated but is allowed to sweep in a vertical plane. The following figures show radarscope pictures of typical echoes and how they are identified.



PPI DISPLAY

INTERPRETATION OF PPI

HOW THE METEOROLOGIST USES RADAR

Radar installations have already been made at some Canadian meteorological stations and similar installations are planned for the future. Such radar sets, especially designed for investigation of weather phenomena, have been a real help to the meteorologist in early detection of thunderstorm development and other forms of severe weather and for short-range forecasting. Research meteorologists have used radar extensively in investigations of precipitation, tornadoes, hurricanes, thunderstorms and, in Canada, the new tool has been particularly valuable in studies of hail formation.

SOUNDING THE UPPER AIR

The earth satellites which are used to probe the outer fringes of the atmosphere have caught the attention of the world. It is, perhaps, not so well known that meteorologists have been investigating the upper atmosphere for over fifty years with ever-improving techniques.

The meteorologist is primarily interested in the atmosphere up to 30,000 metres above the surface. This is actually a comparatively shallow layer of air and if the earth were reduced to the size of an apple this layer of air would be represented by the skin. The air, however, has considerable weight and 9/10 of the total mass of the atmosphere is compressed into this relatively shallow layer. Most of the weather phenomena which affect man's day-to-day activities originate below 30,000 metres.

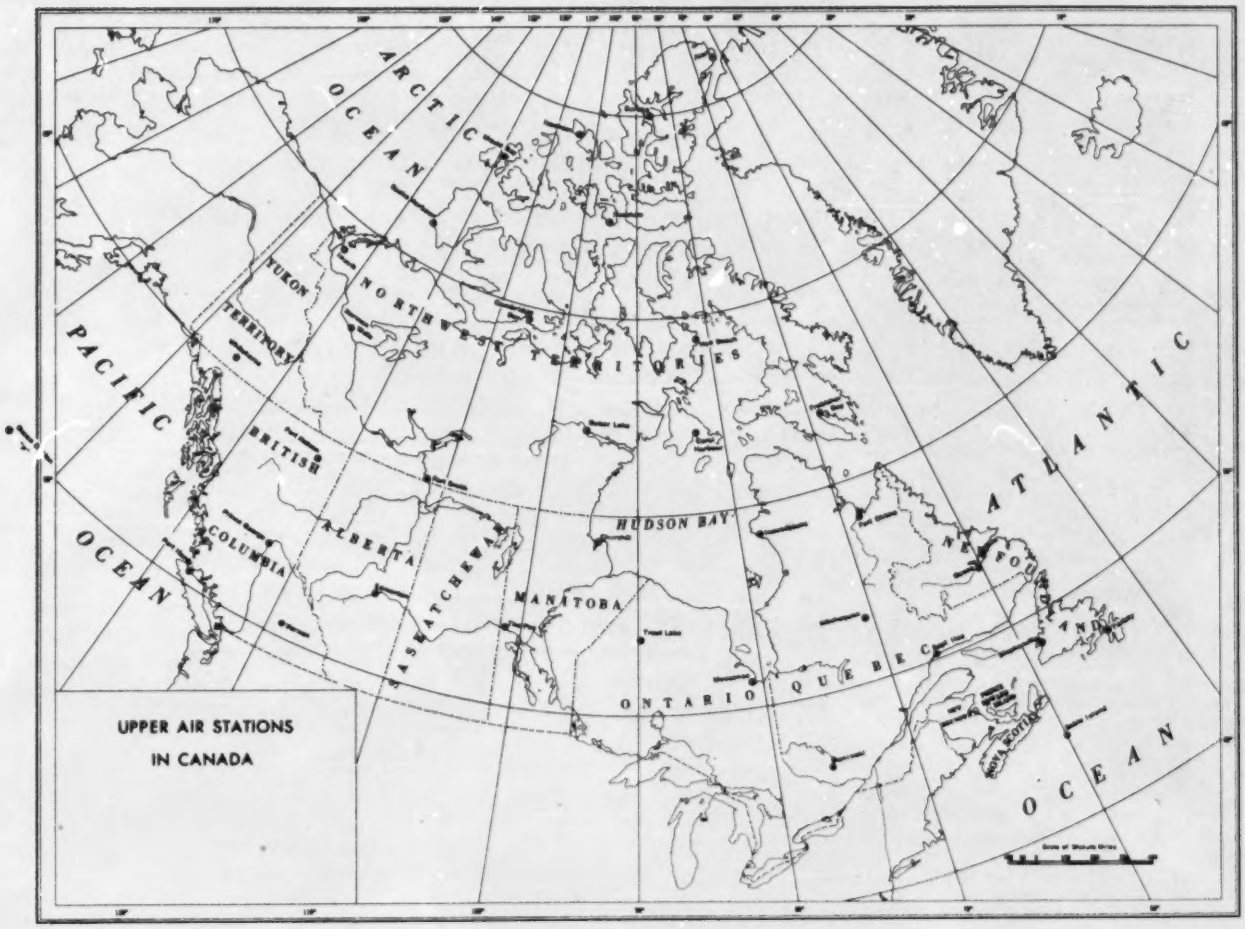
Twice a day, at 12 o'clock noon and 12 o'clock midnight, Greenwich Mean Time, a radiosonde instrument is sent through the atmosphere from 34 upper air stations in Canada. The radiosonde is carried aloft by a large hydrogen-filled rubber balloon from which it is suspended together with a parachute by a length of strong cord. The balloon rises at approximately 300 metres per minute and expands as it rises until it reaches the limit of its strength, at a diameter of about 6 metres, and bursts. This usually occurs somewhere between 25,000 and 30,000 metres.

HOW THE RADIOSONDE WORKS

The radiosonde has sensing elements which measure the pressure, temperature and humidity of the air as it ascends. It also has a small radio transmitter which transmits the information continuously to the ground station. As they ascend, the balloon and instrument drift with the winds and it is therefore possible to calculate the speed and direction of the wind at any level by following the actual course of the radiosonde. The radiosonde is accurately tracked from a ground station by a highly directional radio antenna which serves not only to locate the position of the radiosonde but also to receive the meteorological information.

The materials which are expended in making an upper air observation, including the radiosonde instrument, balloon, battery, hydrogen gas, etc., add up to a cost of approximately $40.00 for each ascent. In order that maximum value may be derived, each ascent is carefully prepared and the data is accurately computed. It takes two men working approximately five hours to complete one upper air observation including the preparation of hydrogen, monitoring the signals, computing and coding the data and finally checking the computations to make sure no errors have been made. The resulting information is sent by a sophisticated radio and landline communication network to a meteorological computer in Toronto and to Weather Offices across the country where the results are analysed and interpreted.

Radiosondes may drift a long way during their ascent into the atmosphere and instruments have been found three to five hundred kilometres from the point of release. However, because of the remote location of most radiosonde stations, very few instruments are recovered. They are constructed with this in mind, however, and are not designed to be used a second time.



Canadian investigations of the upper atmosphere have been carried out for more than thirty-five years. The original sounding equipment was carried aloft by balloons but the information was scratched on a smoked plate by a special pen. These early instruments had to be recovered in order to obtain the information. Other early experiments were also carried out by instrumentation carried aloft on kites. For a brief period in 1935, observations were taken by means of airplanes which rarely got above 6,000 metres.

Although upper air observations are costly from the standpoint of the materials, time and effort expended, the upper air data so derived have now become indispensable to the modern day forecaster. The information provides essential facts which are used in the preparation of today's weather forecasts. Upper air data are also used for research into atmospheric processes and for studies of climate. Forecasting on a global scale and accurate long range forecasts of weeks or even months will only become possible through increased understanding of these processes. A knowledge of the upper winds also has a defense value in the prediction of radioactive fallout from atomic explosion.

WEATHER SATELLITES

NOAA WEATHER SATELLITE

WHAT ARE WEATHER SATELLITES? – The satellites which have been launched into earth orbit over the past two decades or so serve a variety of purposes. However, to the meteorologist one of their most interesting and practical uses is as a "weather eye" in space which looks downward at the vast cloud patterns over the surface of the earth. Pictures of the earth taken from these space vehicles have become important tools to meteorologists seeking to understand and predict the weather by studying the global cloud systems they show.

THE DEVELOPMENT OF WEATHER SATELLITES – The first weather satellite, TIROS (Television Infrared Observational Satellite), was launched in April, 1960, by the United States National Aeronautics and Space Administration (NASA) in cooperation with the National Oceanographic and Atmospheric Administration (NOAA). Early TIROS spacecraft were able to provide pictures of only certain areas of the earth's surface at various angles and sent their data back to only one very complex and costly ground station.

This early series of spacecraft had been redesigned by 1966, and the new and greatly improved satellite was christened ESSA. Its new Automatic Picture Transmission system (APT) made it possible to send satellite pictures to simple ground receiving stations anywhere around the globe. The Atmospheric Environment Service of Fisheries and Environment Canada operated such a station on an experimental basis in 1963. Later, it received satellite photographs on an operational basis daily at Toronto from February, 1966 to March, 1974, when the last such satellite ceased operation.

The current series of weather satellites are called NOAA, after the US National Oceanographic and Atmospheric Administration which is responsible for their development and operation. These satellites circle the globe on a polar orbit (an orbit which crosses both polar regions of the earth) in synchronization with the sun to provide pictures of the entire earth twice each day. These are provided in both the visual and thermal infrared bands of the spectrum.

The visual picture shows surface features of the earth and atmospheric conditions (clouds, etc.) much like an ordinary photograph would. The infrared image shows different surface and cloud-top temperatures in grey tones from black to white. This provides the weather forecaster with important information on cloud-top temperatures and therefore their heights, as cloud-top height relates directly to temperature. The image also provides information on water temperature and currents, ice cover and similar phenomena of interest to the meteorologist. And, of course, it provides a picture at night, when operation in the visual spectrum is not possible.

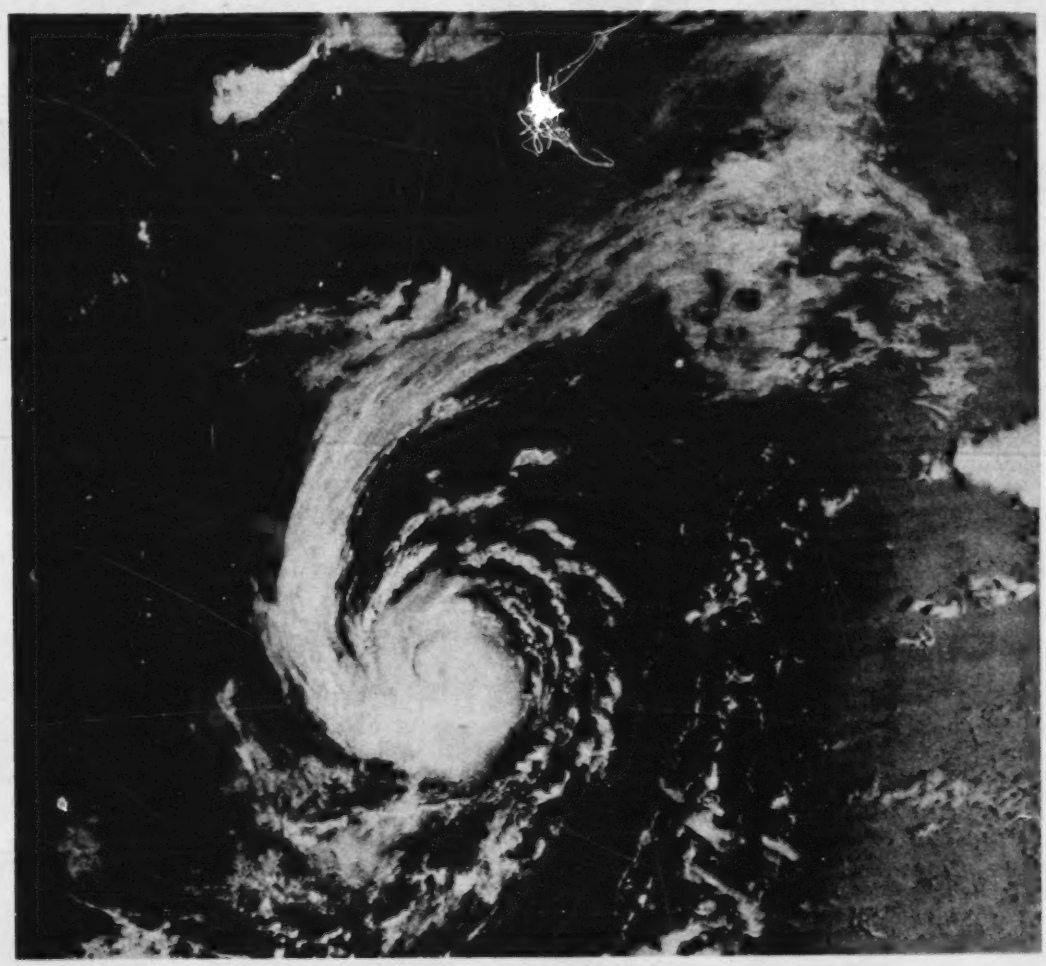
The NOAA satellites are equipped with two sensory systems in each of the two bands (visual and infrared). Of relatively low resolution, images from one – known as a Scanning Radiometer – can be received by a simple APT-type station on the ground. The other is a Very High Resolution Radiometer (VHRR), which provides information at a resolution of 0.9 kilometres but requires a somewhat more complicated ground receiving station. Ground receiving stations of the Atmospheric Environment Service are capable of processing both types of pictures.

In addition to the information available from these polar orbiting spacecraft, weather pictures from space are also provided by a series of geostationary satellites, i.e. satellites which do not change their position in space with reference to the earth. Two of these satellites are located 35,900 km above the equator and view eastern and western North and South America every 30 minutes from the same point in space in both the visual and infrared bands of the spectrum. Geostationary satellites obtain pictures of the earth with the aid of a Visual/Infrared Spin Scan Radiometer (VISSR), which provides a resolution of 0.9 km.

The two US geostationary spacecraft now in orbit are part of a plan by the World Meteorological Organization to girdle the equator with five separate satellites. This would bring the entire globe under weather surveillance throughout the day and night. Japan and the European Space Agency have each already launched satellites destined to become part of this system, and the USSR plans to put the fifth spacecraft of the series into orbit in the near future. In Canada, the Atmospheric Environment Service has installed a dish satellite antenna in November 1977 as a first step to receiving high resolution signals from the geostationary satellites. The receiving station is expected to be completed in the summer of 1978.

Weather satellites are continually being developed and improved. In mid-1978, for example, a new polar orbiting series, TIROS-N, will be launched with two satellites working in tandem to provide world coverage every six hours instead of the present 12-hour cycle. These will provide data in two visual and two infrared spectral bands. Plans for later spacecraft include yet another band, probably microwave, which will be capable of penetrating light cloud cover. Imagery and other data provided by this new series will be available to ground stations of both the APT type and to the more sophisticated advanced VHRR stations anywhere in the world.

Weather satellite imagery shows fronts, squall lines, thunderstorms, hurricanes, potential tornado areas and other meteorological phenomena, as well as ice cover and movement on the open sea or inland water bodies to provide detailed information to the weather or ice forecaster. Other information, such as snow coverage, persistence of cloud formations or of surface conditions on the earth can also be determined from the data provided by these space vehicles. They are a remarkable development of modern technology and will continue to supply more and more information for the benefit of mankind.



NOAA 5 VHRR – SATELLITE PICTURE SHOWING HURRICANE CANDICE OFF THE EAST COAST OF NORTH AMERICA – AUGUST 1976

WEATHER SIGNS

Look for cloudy unsettled weather when

The barometer is falling.
The temperature at night is higher than usual.
The clouds move in different directions at different levels.
High thin white clouds (cirrus) increase. A large ring appears around the sun or moon and stays there until the overcast clouds thicken and obscure the sun or moon.
Summer afternoon clouds darken.

Look for steady precipitation when

There have been signs of unsettled weather and –
The wind is south or southeast, the pressure falling. Rain (or snow) within a day if pressure falling slowly. If falling rapidly, rain soon with winds increasing.
The wind is southeast to northeast, the pressure falling. Rain (or snow) soon.
Thunderclouds developing against a south or southeast wind.

Look for showers when

Thunderclouds develop in a westerly wind.
Cumulus clouds develop rapidly in the spring or summer early afternoon.

Look for clearing weather when

The barometer rises.
The wind shifts into the west or northwest.
The temperature falls.

Look for continued bright weather when

You can look directly at the sun when it sets like a ball of fire.
The barometer is steady or slowly rising.
Cloudiness decreases after 3 p.m. or 4 p.m.
Morning fog breaks within two hours after sunrise.
There is a light breeze from the west or northwest.
There is a red sunset.

Look for higher temperatures when

The barometer falls. In summer a falling barometer may indicate cloudy weather which will be cooler than clear weather.
The wind swings away from the north or the west.
When the morning sky is clear, except when the barometer is high or is rising in winter-time, or if the wind is strong from the north or west.

Look for lower temperatures when

The wind swings from the southwest into the west, or from the west into the northwest or north.
When skies are clearing – (although clearing skies in the morning will likely mean warmer weather by afternoon, particularly in the summer).
In the winter, the barometer rises.
Snowflurries occur with a west or north wind.
Pressure is low and falling rapidly, wind east or northeast and backing slowly into north. (The fall in temperature will be gradual.)

CLOUDS

Since earliest years, the human race has been interested in cloud formations. This interest is due to the ever-changing, spectacular nature of cloud patterns, and to the fact that significant weather phenomena often accompany certain clouds. Fishermen and shepherds even learned to associate cloud shapes with future weather, although they did not know how clouds are formed.

WHAT ARE CLOUDS MADE OF?

Simply put, clouds are made of water. More precisely, clouds are composed of tiny water droplets or ice crystals. In some cases the water droplets may persist at temperatures well below freezing. Such droplets are said to be supercooled. Clouds made up mainly of ice crystals look fuzzy and diffuse. Those made up chiefly of water droplets have sharp, well defined edges.

HOW ARE CLOUDS CLASSIFIED?

Clouds are divided into four families, according to appearance and height. Clouds of the *high* family are usually based above 6,000 metres. Middle clouds are usually based between 2,000 and 6,000 metres. Bases of low clouds range from near the ground to 2,000 metres. The fourth family includes certain clouds which have a common appearance, but which have bases varying within the range of both the middle and the low families. Because of their appearance, they are called clouds of *Vertical Development.*

It should be noted that the height of the cloud top is not considered in this classification. For example, a cloud which is based at 1,500 metres and topped at 2,500 metres, and which does not belong to the vertical development family, would be classified as a low cloud.

Each family is subdivided on the basis of appearance. For example, a family member which displays a uniform base with no markings is called *stratus* (meaning sheet or layer), while a cloud which has a base showing a definite pattern or structure is called *cumulus* (meaning lumpy or billowy, from the Latin *'pile'* or *'heap'*). Some clouds are predominantly precipitation clouds and these are designated *nimbus* (meaning rain). A cloud that looks like a streak is called *cirrus* (meaning hair).

These names may be combined together as for instance, nimbostratus (a raining cloud); or cumulonimbus, a raining heap cloud (shower cloud); cirrostratus, a layer of streak clouds; stratocumulus, a lumpy or patterned layer cloud; cirrocumulus, lumpy or billowy clouds amongst streak clouds; alto-stratus, a diffuse sheet cloud at middle levels of the atmosphere; altocumulus, a dappled or billowy cloud at middle levels (alto, from the Latin meaning *middle range).*

HOW MANY MAIN TYPES OF CLOUDS ARE THERE?

The cloud classification involves ten main types, shown in the following table:

High Clouds	*Middle Clouds*
(base 6,000 to 12,000 metres)	*(base 2,000 to 6,000 metres)*
Cirrus	Altostratus
Cirrostratus	Altocumulus
Cirrocumulus	
Low Clouds	*Clouds of Vertical Development*
(base from surface of ground to 2,000 metres)	*(base 500 metres and up)*
Stratus	Cumulus
Nimbostratus	Cumulonimbus
Stratocumulus	

CIRRUS

Detached or discontinuous clouds in the form of white, delicate filaments or white patches or narrow bands. Have a fibrous, hair-like, silky appearance. Composed of ice crystals. Sometimes shaped like a comma, terminating at the top in a hook or a tuft. Sometimes arranged in broad parallel bands, converging towards the horizon.

CIRROCUMULUS

Thin, white patch, sheet or layer, without shading, composed of very small elements in the form of grains, ripples, etc., merged or separate, more or less regularly arranged; most of the elements have an apparent width of less than one degree.* Composed of ice crystals. Transparent enough to reveal sun or moon. Corona is sometimes observed in this cloud.

CIRROSTRATUS

Transparent, whitish cloud veil of fibrous, hair-like or smooth appearance, totally or partly covering the sky, and generally producing halo phenomena. Composed mainly of ice crystals. Never thick enough to prevent objects on the ground from casting shadows, except when the sun is low. Sometimes the veil of cirrostratus is so thin that a halo provides the only indication of its presence.

ALTOCUMULUS

White or grey (or both white and grey) patch, sheet or layer of cloud, generally with shading, composed of laminae, rounded masses, rolls, etc., which are sometimes partly fibrous or diffuse and which may or may not be merged; most of the regularly arranged small elements usually have an apparent width between one and five degrees.* Composed in the main of water droplets. Occurs most commonly as an extensive sheet of cloudlets, fairly regularly arranged. Sometimes cloudlets are in elongated parallel rolls, often separated by clear lanes. Sheets often occur simultaneously at two or more levels. Transparency varies considerably, often masking sun completely.

ALTOSTRATUS

Greyish or bluish cloud sheet or layer of striated, fibrous or uniform appearance, totally or partly covering the sky, and having parts thin enough to reveal the sun at least vaguely, as through ground glass. Thicker parts will mask the sun completely. Does not show halo phenomena. Composed of water droplets and ice crystals; also contains raindrops and snowflakes. When precipitating, is usually of the continuous type: rain, snow, or ice pellets.

NIMBOSTRATUS

Grey cloud layer, often dark, the appearance of which is rendered diffuse by more or less continuously falling rain or snow, which in most cases reaches the ground. Thick enough to blot out the sun. Low, ragged clouds frequently occur below the layer. Composed of water droplets, raindrops, snow crystals, snowflakes.

STRATOCUMULUS

Grey (or whitish) patch or sheet layer of cloud which almost always has dark parts, made up of rounded masses, rolls, cloudlets, etc. which are non-fibrous. Most of the regularly arranged cloudlets have an apparent width of more than five degrees.* Composed of water droplets, sometimes raindrops or snow pellets and more rarely, of snow crystals and snowflakes. Varies greatly in transparency. Sometimes accompanied by weak precipitation: rain, snow or snow pellets.

STRATUS

Generally grey cloud layer with a fairly uniform base, which may give drizzle or snow grains. When the sun is visible through the cloud, its outline is clearly discernible. Does not produce haloes. Composed of small water droplets (or ice particles at low temperatures). Base often low enough to obscure tops of low hills or high buildings. When thin, produces a corona round the sun or moon.

CUMULUS

Detached clouds, generally dense and with sharp outlines, developing vertically in the form of rising mounds, domes or towers, of which the bulging upper part often resembles a cauliflower. The sunlit parts are mostly brilliant white; the base is relatively dark and nearly horizontal. Composed mainly of water droplets; ice crystals may form in parts colder than 0°C. Cumulus of great vertical extent may produce showers of rain or snow.

CUMULONIMBUS

Heavy and dense cloud, with a considerable vertical extent, in the form of a mountain or huge towers. Part of its upper portion is usually smooth, or fibrous, or striated and nearly always flattened; this part often spreads out in the shape of an anvil or dark plume. Under the base of this cloud which is often very dark there are frequently low ragged clouds. Composed of water droplets and, especially in upper portion, of ice crystals. Also contains large raindrops and often snowflakes, snow pellets, ice pellets or hailstones. The size of this cloud is so great that its characteristic shape can only be seen from a considerable distance. Cloud may be isolated or one of a continuous line, like a wall. The dark, menacing or even terrifying aspect of *Cumulonimbus* is usually enhanced by thunder and lightning and may be accentuated by intense showers or rain, snow or hail, by squalls and by hanging protuberances.

*One degree: approximately the apparent width of the little finger at arms length. (Five degrees = 8 fingers)

IS LIGHTNING REALLY DANGEROUS?

Many believe that animals draw lightning and that open windows and doors invite lightning to come inside. Others say it never strikes twice in the same place and you're safe if you stay where lightning struck once before.

Although people do continue to be struck by lightning occasionally, such an accident is actually quite rare. In Canada the chances are only one in a million of being in the path of a lightning stroke, while the odds of being in an auto accident and not living through it are two hundred times greater. Actually, the bark of the thunderstorm is worse than its bite, for nine out of ten lightning discharges go from cloud to cloud or between parts of the same cloud and never reach the earth at all, and most of those that do strike the ground cause little or no harm or damage.

But each year a few people do get struck by lightning, and a great many worry and wonder about it. Here are a few facts to help you understand it better. Lightning is the discharge of static electricity which has gradually built up within a towering cloud until it is great enough to break through the resistance of the air and jump as a giant spark between either charged parts of the clouds or the cloud and the ground.

There are many beliefs about lightning, some true some false. Test yourself with this quiz and check with the answers on the reverse side.

1. It's dangerous to leave windows and doors open during a lightning storm.
2. When caught out in the open in a thunderstorm, take shelter under a tree.
3. You're safer in the city than in the country during a lightning storm.
4. When a thunderstorm occurs while you're driving in your car, it's best to get out and away from the automobile.
5. Lightning never strikes twice in the same place.
6. Thunder can be just as dangerous as lightning.
7. Toronto has more thunderstorms per year than has Vancouver.

ANSWERS:

1. F. – Closing windows and doors will keep out the rain, but otherwise has practically no effect on lightning.

2. F – That tree is too good a target for the lightning discharge, and you could be right in the path. Animals are sometimes killed when they huddle under isolated trees for shelter.

3. T – The large number of tall buildings properly grounded, lead the lightning charge off harmlessly to the ground.

4. F – Your all-steel automobile will safely protect you – but if the rain is heavy you might be well advised to stop and drive on when the visibility is better.

5. F – Lightning often strikes the same place more than once. The Empire State Building has been struck 9 times in 20 minutes.

6. F – Thunder is just the sound of lightning discharge – it can't hurt you. One lightning expert puts it this way "If you heard thunder, the lightning didn't strike you. If you saw the lightning, it missed you; and if it did strike you, you don't know it now".

7. T – Toronto has an average of 22 thunderstorms a year; Vancouver only 4.

HURRICANES

In Japan they call them typhoons, in Bengal they're called cyclones, in Australia they say "willy-willies", here in North America we refer to hurricanes, but whatever the name, these tropical storms leave behind them floods, devastation and death.

Hurricanes are born in tropical regions and when they are fully developed they are the most destructive of all storms. Actually, the winds of a tornado blow with greater force, but the width of a tornado is small, about 0.5 kilometre wide on the average. On the other hand, it is not unusual for the violent winds of the hurricane to cover thousands of square kilometres.

Briefly here's what a hurricane is like. At the outer fringe of the storm area, the winds are gusty but less than 30 kilometres per hour. As you go towards the "eye" of calm at the centre the speed increases gradually. Squalls are followed by furious gales and, finally, if the hurricane is a severe one, the winds immediately surrounding the centre whirl at tremendous speeds. These winds create huge waves on the ocean and ships are occasionally carried to the ocean bottom. If the hurricane moves onto the land, the crops in the fields and the orchards are destroyed, buildings are wrecked, trees uprooted and the wreckage is carried along with the wind.

The task of forecasting the path and the speed of hurricanes is one of the most exasperating problems facing a weather forecaster. Hurricanes tend to be rugged individualists in their actions, and seem to refuse to abide by any set of rules. Because a difference of position of only 80 kilometres can make the difference between terrific destruction and only a heavy gale with minor damage, the importance of forecasting their future course as accurately as possible is readily apparent. Despite these difficulties, the Weather Services of the United States and Canada have been able to save many lives by providing advance warning of a hurricane's arrival.

Here are some random facts about hurricanes which may interest you.

1. Maximum wind speeds in a hurricane may reach 400 km/h and may average over 250 km/h.
2. The "eye" of a hurricane is the calm centre around which blow the highest winds.
3. In North America the hurricane season is from May to December. The majority of storms occur in September, with October running a close second.
4. In the past 50 years, 25 tropical hurricanes have passed over or close to Ontario and eight of these storms have produced violent winds and excessive rainfall.
5. The most deadly hurricane in all history was in the region of the Bay of Bengal in 1737 when 300,000 persons were drowned.
6. Weathermen give names to hurricanes so that they may readily keep track of several storms at one time. Lists of girl's names are prepared in advance each year.
7. Although the winds in a hurricane reach speeds of hundreds of kilometres per hour, the storm centre itself moves relatively slowly. The fastest moving storm on record was that of 1938 in New England and that storm moved only 90 km/h.
8. Hurricanes do not occur on the west coast of Canada.

TORNADOES

INFANT TORNADO

ADULT TORNADO

DYING TORNADO

Three stages in the life-cycle of a tornado as witnessed by LAC M.A. Herron on June 13, 1953 at Moose Jaw, Sask.

WHAT THEY ARE – The tornado, sometimes called "twister" or "cyclone" is a violent local vortex in the atmosphere. It has a funnel-shaped cloud with upward spiralling winds of terrific velocity. In area, it is one of the least extensive of all storms, but in violence it is the world's most severe. More tornadoes occur in the United States than in any other country, but fortunately they seldom occur in Canada – chiefly in Saskatchewan and Southern Ontario. Here, only about one a year causes loss of life or extensive damage.

WHEN THEY OCCUR – Tornadoes in the United States have occurred in every month of the year and at all times of the day, but they are most prevalent in May and June between 3 and 6 p.m. and rarely occur after 9 p.m.

SIZE AND EXTENT – Tornadoes have an average length of path of about 15 to 65 kilometres but on occasion have reached nearly 500 kilometres. The widths of path average about 275-375 metres but on isolated occasions have cut swaths as narrow as a few metres and as wide as 1.5 kilometres.

WINDS IN A TORNADO – Wind speeds within the vortex of a tornado have never been measured, but have been estimated as high as 800 kilometres per hour. The tornado itself moves about 70 kilometres per hour.

WHAT THEY LOOK LIKE – Clouds associated with the occurrence of a tornado are dark heavy cumulonimbus (the familiar thunderstorm cloud) from which a whirling funnel-shaped "elephant's trunk" often extends to the ground. Rain, and frequently hail, precede the storm and a heavy downpour usually follows the tornado's passage.

DAMAGE THEY DO – Destructive effects of a tornado are terrifying. Strong buildings are torn apart; large trees are uprooted; people and farm animals are whirled through the air; bridges are wrenched from their foundations. Reduced air pressure within the funnel-shaped cloud of the tornado causes buildings literally to explode when the storm passes directly overhead, the glass windows being blown to the outside by the greater air pressure within the building. There is often a surprisingly sharp line dividing the area of almost complete destruction from the adjacent area of little damage.

SAFETY DURING A TORNADO – The safest place during a tornado is the so-called "cyclone cellar" consisting of a well constructed underground room or cellar near the house. If such a haven is not available the southwest corner of a frame building affords a measure of safety. Modern, reinforced office buildings are usually quite safe, too. If the tornado is seen beforehand and its direction of movement noted, it is possible to keep out of its way by fleeing at right angles to the direction of movement. Tornadoes usually move from the southwest to the northeast.

AIR POLLUTION AND WEATHER

Air pollution is very much in the news today. We hear that smog is a hidden peril that fouls the air in our cities, endangers our health, and may even render the earth uninhabitable if allowed to go unchecked.

WHAT IS AIR POLLUTION?

Any material in the air that causes man discomfort, interferes with his health, or damages his property may be called air pollution.

There are two main kinds of air pollution. The first is smoke, particles of soot or ash resulting from combustion (burning). Most people are familiar with this kind of pollution because it is usually visible. Gases such as sulphur dioxide and hydrogen sulphide are invisible, and they make up the second kind of pollution. Many of man's activities produce these and other gases; the burning of fuel oil and various industrial processes are examples. Ozone is another important air pollutant. This very active gas is formed by the action of strong sunlight on automobile exhaust fumes.

HOW LONG HAS POLLUTION BEEN WITH US?

Air pollution is not a new problem. As long ago as the 14th century the widespread burning of soft coal shrouded London, England in a blanket of choking smoke. Laws were passed banning black smoke on penalty of death, and one man was hanged for this offence. However, it was in the 19th century that pollution became a serious problem as industry expanded and cities mushroomed in size. Today pollution from smoke is not as serious as it once was, but pollution from ozone and other gases is worse than ever before.

WHAT ARE THE EFFECTS OF AIR POLLUTION?

Air pollution has many harmful effects. It corrodes metals, fades paint, and cracks rubber tires. Soot increases laundry and dry cleaning bills. Sulphur dioxide and ozone can damage or kill trees and plants. The cost of all this is enormous, and some estimates run as high as $40 per year for every man, woman and child in Canada.

Of much more importance than property damage is the effect that pollution has on our health. Diseases such as emphysema, bronchitis, and asthma are made more severe by air pollution, and there is evidence that it is a contributing factor in lung cancer. While scientists are still trying to determine the exact effect of air pollution on humans, there is no doubt that it is harmful. In 1952, 4000 deaths resulted from the great London smog. There have been other pollution disasters in Mexico, the United States, and Belgium. No such disasters have as yet happened in Canada, but in November, 1962 a serious smog situation in southern Ontario brought Toronto very near the critical danger point.

HOW DOES THE WEATHER AFFECT AIR POLLUTION?

Meteorology and air pollution are related in many ways. Perhaps the most obvious effect is the increase in average levels of pollution that takes place in cold weather. In winter more fuel is burned in homes and factories for heating purposes and so there is more smoke than in the summer.

Another factor that influences the concentration of air pollutants is atmospheric *turbulence.* Turbulence is the uneven or irregular motion of the air and is greatest when the wind is strong and gusty. With turbulent air smoke and gases are blown about and mixed over a large area. On the other hand, pollution is worst when the wind is light and steady and there is little turbulence. Wind direction affects the movement of smoke. For example, if the wind is from the north it will blow the smoke pollution towards the south.

If you live in a large city you can observe for yourself the effect of wind and turbulence on pollution. On a day when winds are light the air may be smoky or hazy, and the pollutants will give the sky a whitish colour. Look again when the wind is strong and blustery, and you will see that the air is clean, and the sky is a bright, clear blue.

Meteorologists can estimate the degree of turbulence by measuring the lapse rate of temperature. The lapse rate is simply the way in which the temperature changes in the vertical. Usually it gets colder as we go up into the air. Under these conditions there will be enough turbulence to spread pollutants over a large area. Sometimes however, the air is warmer above than in the lower levels. This is called a temperature inversion. In this case there is little turbulence and smoke and gases will collect near the ground. Fortunately inversions are usually short lived, often forming only at night and breaking up at dawn, but occasionally they last for days. This allows the trapped pollutants to build up to a high level and is what happened during the pollution disasters mentioned earlier.

Turbulence produces what the meteorologist calls *diffusion.* You can demonstrate diffusion by a simple experiment. Fill a jar or glass with water and gently drop in a small amount of ink. The colour will spread and become fainter. This is diffusion and the same thing happens to a puff of smoke released into the air.

You can make this experiment more interesting by allowing the water to become perfectly still before putting in the ink. The ink will then be slower to diffuse. Smoke released into very still air would behave in a similar way. Cooling or heating the water from below will also have an interesting effect on the diffusion of the ink.

WHAT CAN BE DONE ABOUT AIR POLLUTION?

In Canada, there are many things that can be done, and are being done, to get rid of or reduce air pollution. Most provinces and cities have laws to limit the amount of pollutants that can be emitted. Industries can install filters in chimneys. In the United States all new cars must have after-burners, devices which remove harmful gases from automobile exhausts. Meteorologists can forecast periods of poor diffusion, and industries can cut down on the release of pollutants during these periods. The citizen can help too, by operating his home heating unit in the proper way, thus avoiding a smoking chimney.

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